Electronic Devices and Circuits

EME306

(Summer 2021-2022)

Lecture 9

Diode Types and Applications

INSTRUCTOR

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➢ Contents

DIODE LIMITERS (CLIPPER)

- Positive Diode Limiters
- Figure shows a diode positive limiter (also called clipper) that limits or clips the positive part of the input voltage.

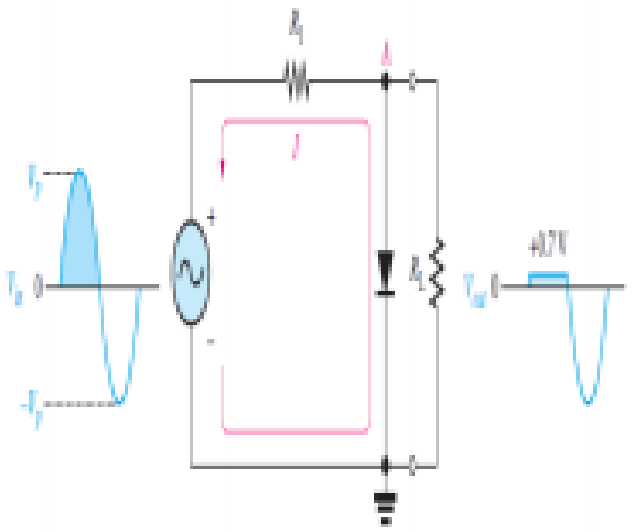
At +ve half cycle

- If Vin<0.7 v, diode off

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right)V_{(in)}$$

So V_{out} is directly proportional to V_{in}

- If Vin ≥ 0.7 v, diode on, V_{out}=0.7v



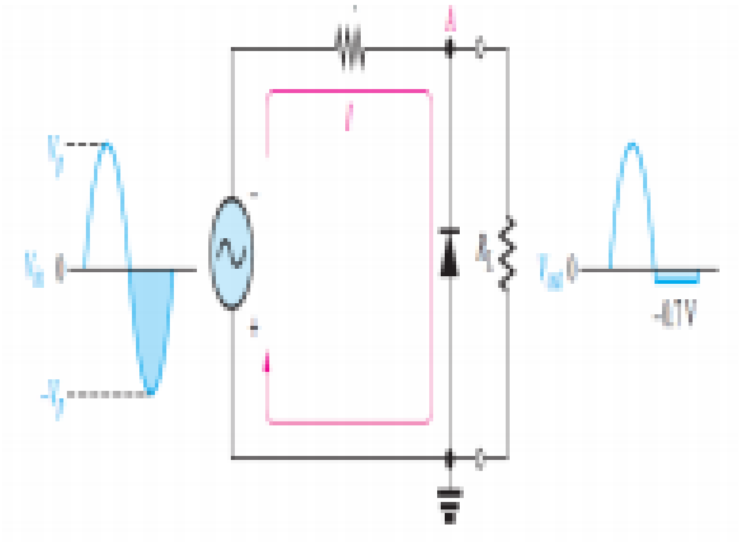
At -ve half cycle

- Diode off and

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right)V_{(in)}$$

So V_{out} is directly proportional to V_{in}

Negative Diode Limiters



<u>At +ve half cycle</u>

- Diode off, so

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{(in)}$$

So V_{out} is directly proportional to V_{in}

<u>At +ve half cycle</u>

- If $v_{in} > (-0.7)$, diode off and

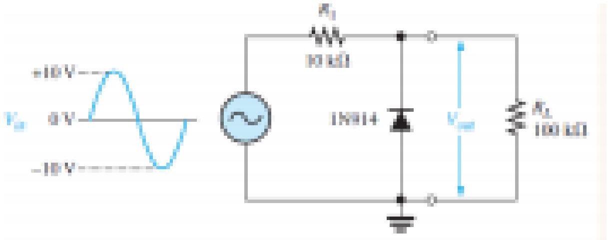
$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{(in)}$$

So V_{out} is directly proportional to V_{in}

- If $v_{in} \leq (-0.7)$, diode on and $V_{out} = -0.7v$

Example

- What would you expect to see displayed on an oscilloscope connected across RL in the limiter shown in Figure?

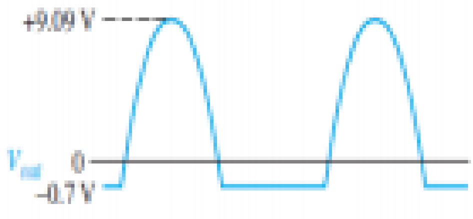


At +ve half cycle

- Diode off, so $V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{(in)}$

So V_{out} is directly proportional to V_{in}

$$V_{P(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{p(in)} = \left(\frac{100}{10+100}\right) 10 = 9.09V$$



At -ve half cycle

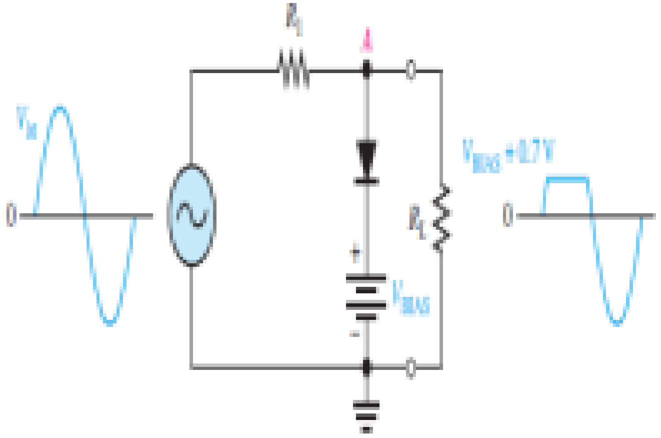
- If $v_{in} > (-0.7)$, diode off and $V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{(in)}$

  So V_{out} is directly proportional to V_{in}

- If $v_{in} \leq (-0.7)$, diode on and $V_{out} = -0.7v$

Biased Limiters

- +ve biased limiter



For +ve half cycle

- If v_{in}<(V_{Bias}+0.7) diode is off , and

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right)V_{(in)}$$

So V_{out} is directly proportional to V_{in}

- If $v_{in} \geq$ (V_{Bias}+0.7) diode will be on , and V_{out}=(V_{Bias}+0.7)

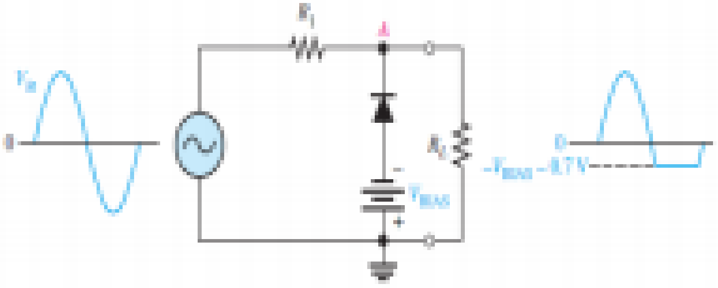
For –ve half cycle

Diode is off, so

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right)V_{(in)}$$

So V_{out} is directly proportional to V_{in}

-ve biased limiter



For +ve half cycle

- Diode is off all times, then

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L} \right) V_{(in)}$$

So V_{out} is directly proportional to V_{in}

For - ve half cycle

- If $v_{in} > -(V_{Bias}+0.7)$ diode is off , and

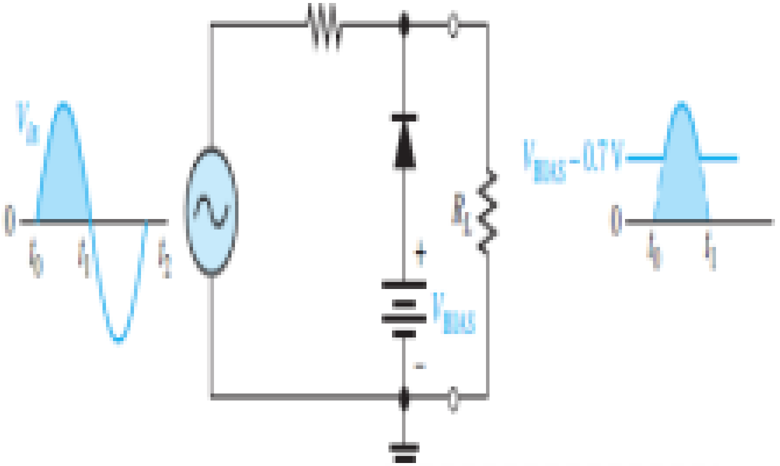
$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L} \right) V_{(in)}$$ So V_{out} is directly proportional to V_{in}

- If $v_{in} \leq -(V_{Bias}+0.7)$ diode will be on , and $V_{out}=-(V_{Bias}+0.7)$

Another circuits

For +ve half cycle

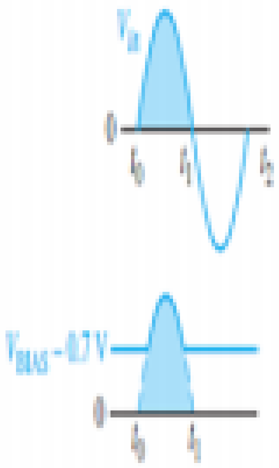
- If $v_{in} < (V_{Bias} - 0.7)$ diode will be on , and $V_{out} = V_{Bias} - 0.7$



- If $v_{in} \geq (V_{Bias} - 0.7)$ diode will be off , and

$$V_{(out)} = \left(\frac{R_L}{R_1 + R_L}\right) V_{(in)}$$

, So V_{out} is directly proportional to V_{in}



For -ve half cycle

diode will be on , and $V_{out} = V_{Bias} - 0.7$

EXAMPLE 2

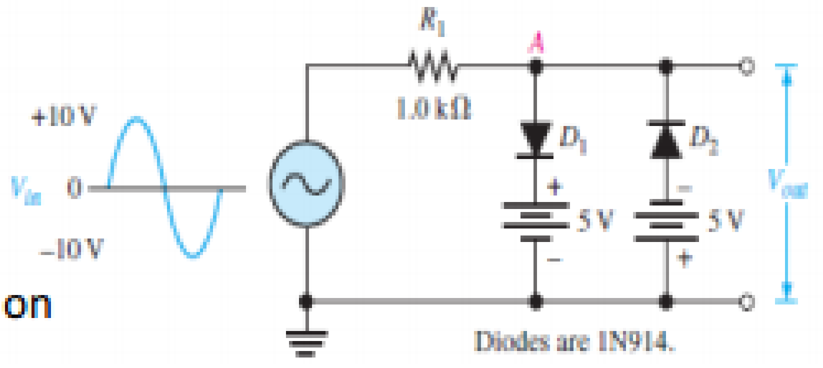
- Figure shows a circuit combining a positive limiter with a negative limiter. Determine the output voltage waveform.

<u>**For +ve half cycle**</u>

D_2 will be off all times

<u>For diode D_1</u>

- If $v_{in}<(5+0.7)$, D_1 will be off and $V_{out}=V_{in}$
- If $v_{in}\geq(5+0.7)$ diode will be on , and V_{out} $=5+0.7=5.7V$

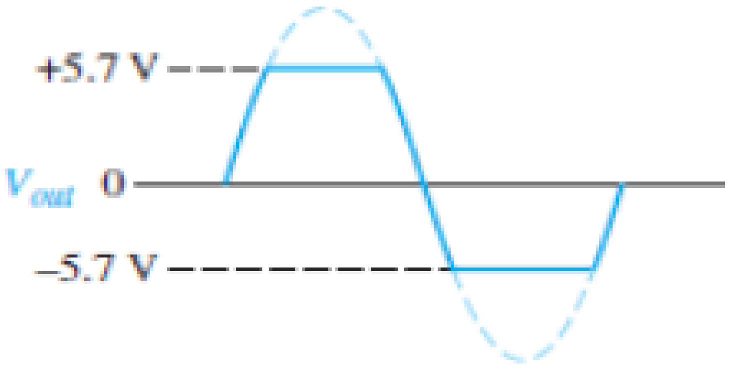


<u>**For -ve half cycle**</u>

D_1 will be off all times

<u>For diode D_2</u>

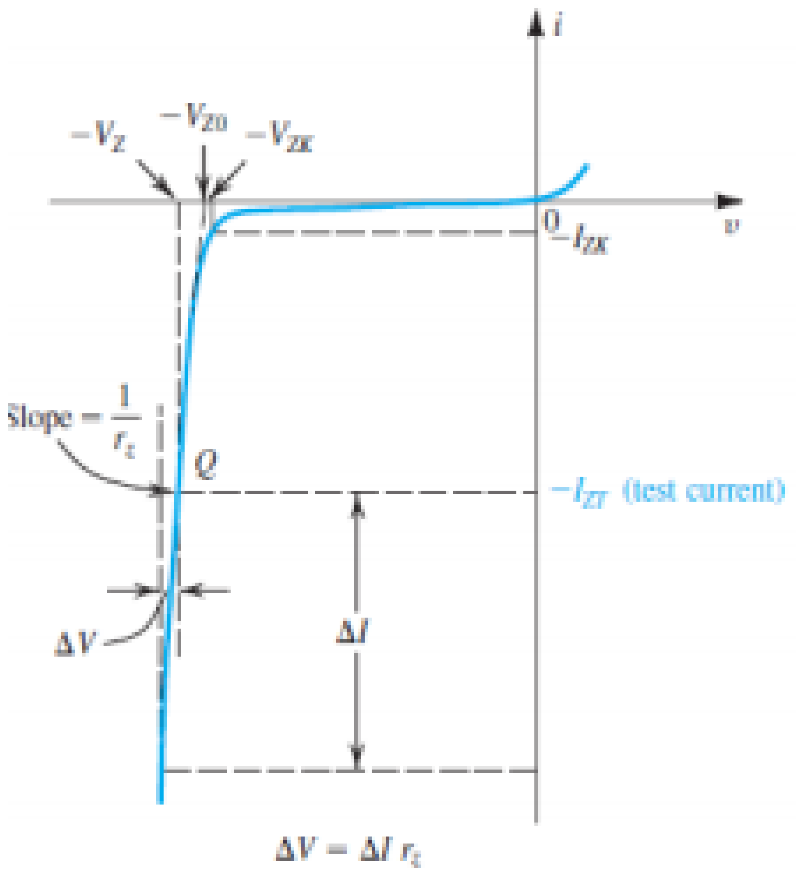
- If $v_{in}>(-5-0.7)$, D_1 will be off and $V_{out}=V_{in}$
- If $v_{in}\leq(-5-0.7)$ diode will be on , and $V_{out}=-5-0.7=-5.7V$



THE ZENER DIODE

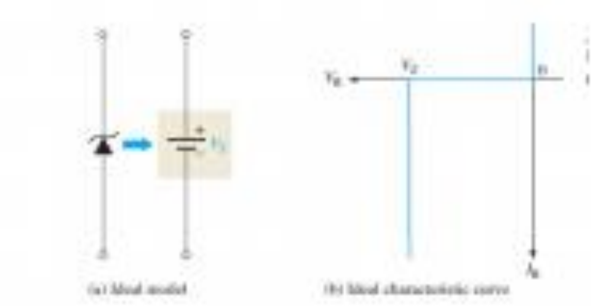
- A zener diode is a silicon pn junction device that is designed for operation in the reverse-breakdown region.

- The breakdown voltage of a zener diode is set by carefully controlling the doping level during manufacture.

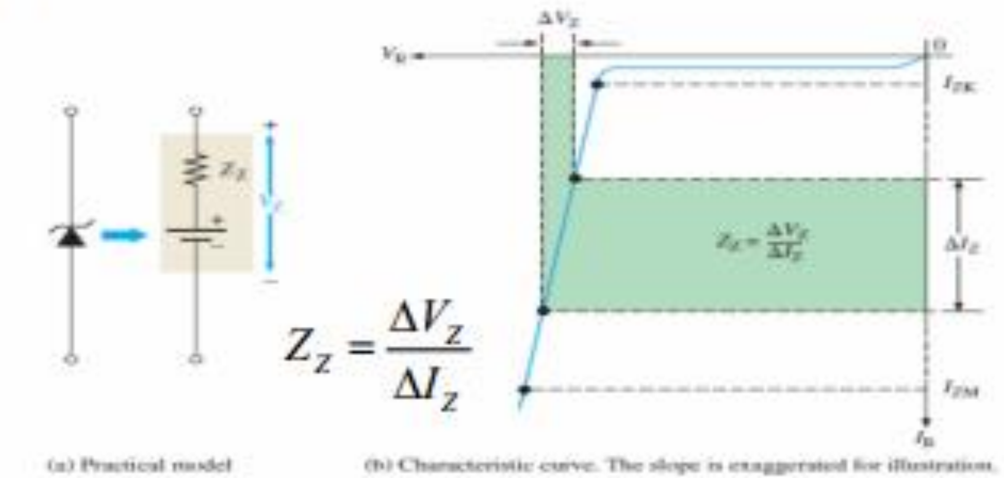


Zener Equivalent Circuits

1- The ideal model



2- The practical model



$$Z_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

Z_z (r_Z) is the dynamic resistance and it is in the range of a few ohms to a few tens of ohms

For $V_Z < V_{Zo}$

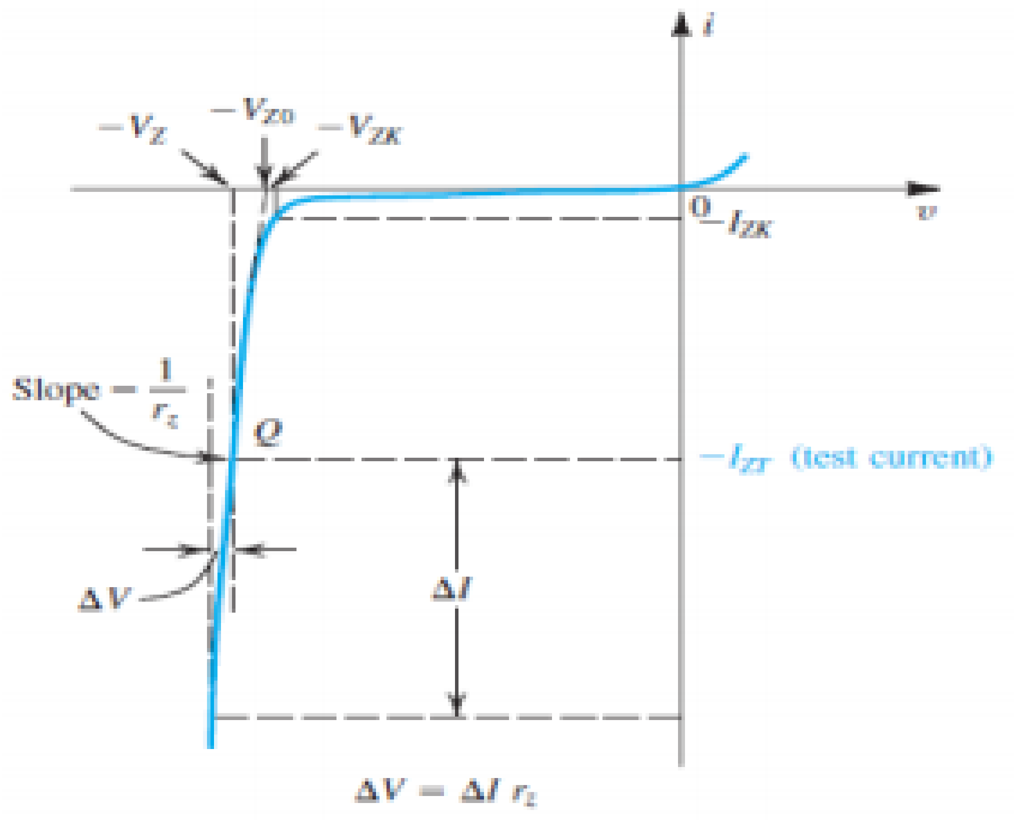
$$V_Z = V_{ZO} - \Delta I_Z r_z$$

For $V_Z > V_{Zo}$

$$V_Z = V_{ZO} + \Delta I_Z r_z$$

Zener power dissipation

$$P_Z = V_Z * I_Z$$



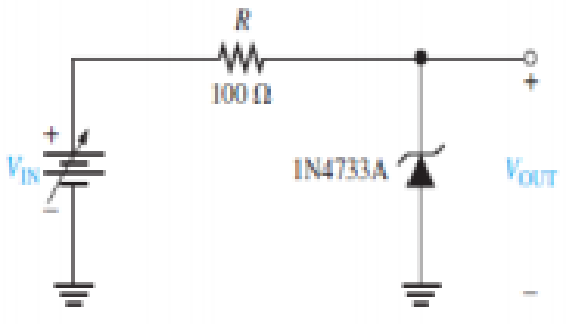
The lower the value of r_z is, the more constant the Zener voltage remains as its current varies, and thus used in the design of voltage regulators.

Zener applications

- Zener Regulation with a Variable input

Example

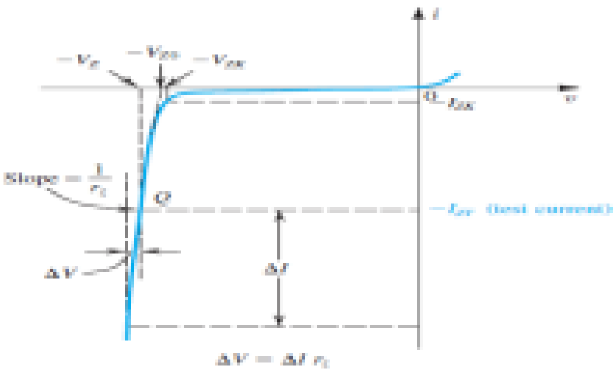
Determine the minimum and the maximum input voltages that can be regulated by the zener diode. Given V_Z = 5.1 V at I_Z 49 mA, I_{ZK} =1 mA, and r_Z=7Ω at I_Z, and P_{Dmax}=1watt



For I_Z=1 mA and V_Z<V_{ZO}

$$V_Z = V_{ZO} - \Delta I_Z r_z$$

$$V_Z = 5.1 - (49-1)mA * 7\Omega = 4.76v$$



$$V_{in(\min)} = V_Z + I_{ZK} * 100\Omega$$

$$V_{in(\min)} = 4.76 + 1mA * 100\Omega$$

$$= 4.86v$$

For P_{Dmax}=1watt,
then I_{zmax}= (P_{Dmax}/Vz)
= (1W/5.1v)= 196mA

For I_Z=196 mA and V_Z>V_{ZO}

$$V_Z = V_{ZO} + \Delta I_Z r_z$$

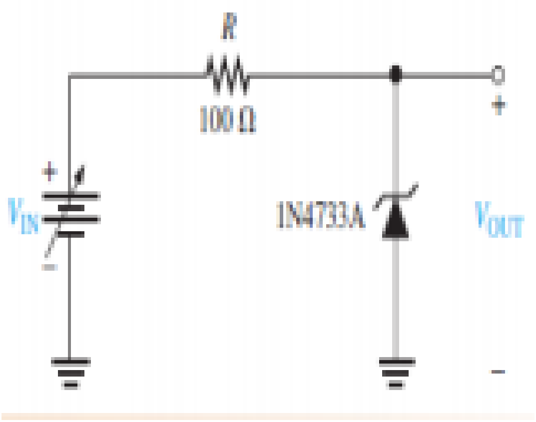
$$V_Z = 5.1 + (196-49)mA * 7\Omega = 6.129v$$

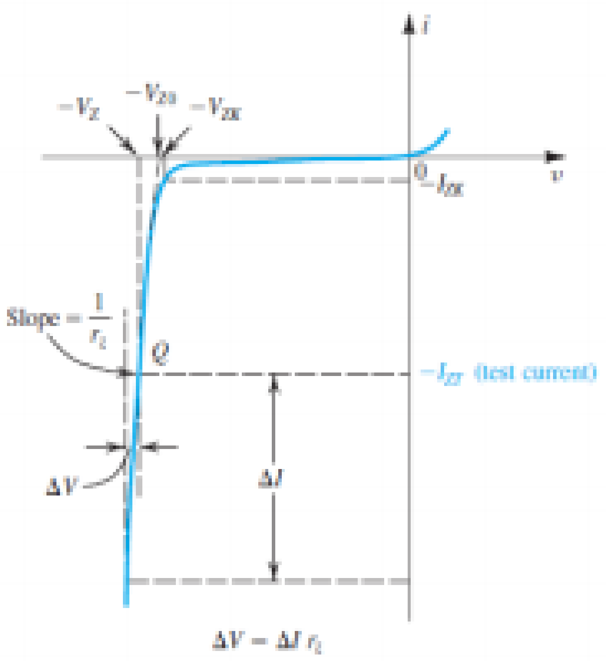
$$V_{in(\max)} = V_Z + I_{Zm} * 100\Omega$$

$$V_{in(\max)} = 6.129 + 196mA * 100\Omega$$

$$= 25.729v$$

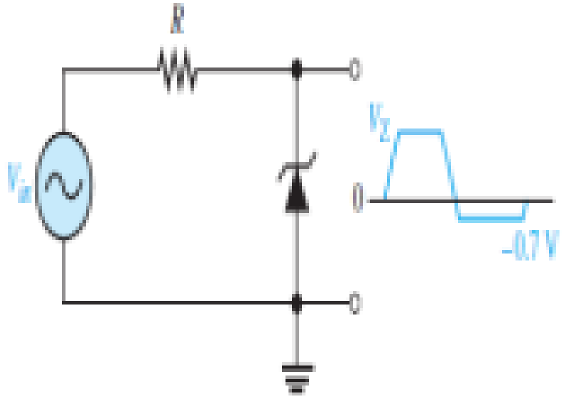
$$4.86v < V_{in} < 25.729v$$

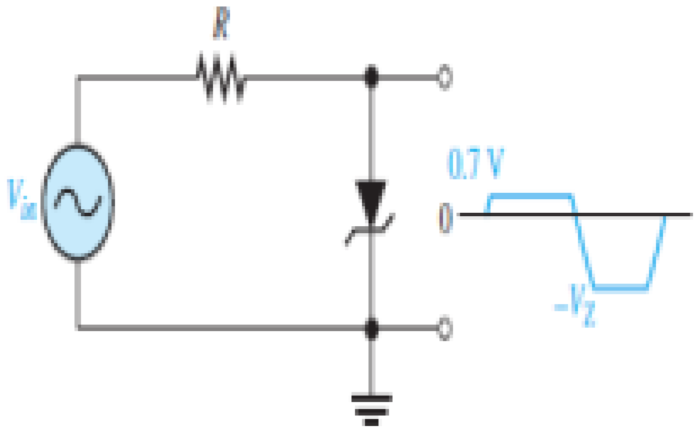


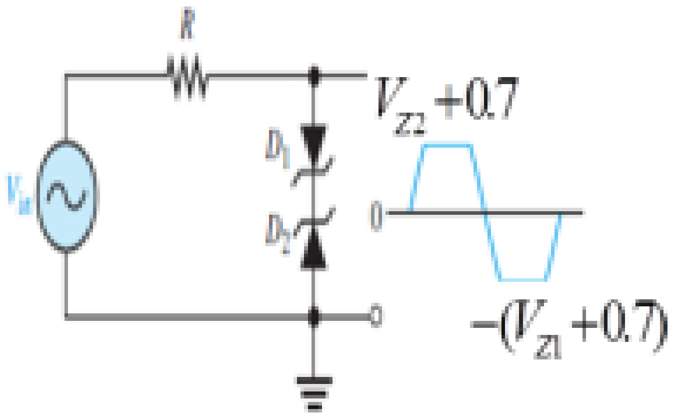


Zener Limiter

- In forward region connection, it work as regular diode, but in reverse bias connection work as zener diode (battery)

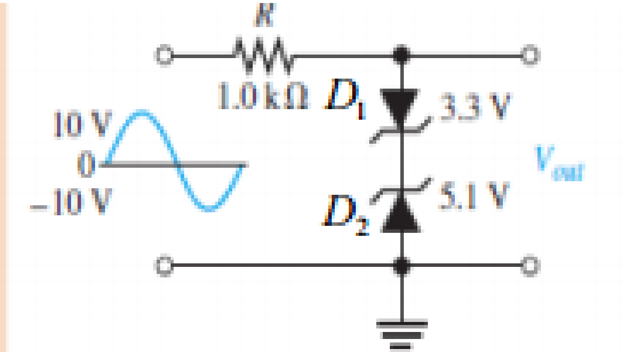






Example

For the circuit shown, sketch the o/p voltage



For +ve half cycle,
D_1 work as regular diode and have voltage drop of 0.7v, while D_2 work as zener diode with voltage drop 5.1v, so
V_o=0.7+5.1=5.8v

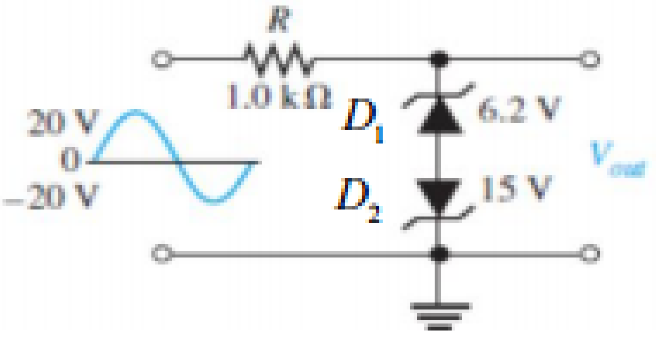
For -ve half cycle,
D_2 work as regular diode and have voltage drop of - (- 0.7)v, while D_1 work as zener diode with voltage drop (-3.3)v, so
V_o=-0.7-3.3=- 4.0

0.7+5.1=5.8

-0.7-3.3= - 4.0

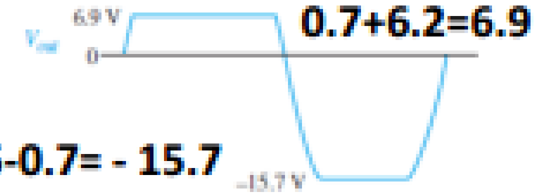
Example

For the circuit shown, sketch the o/p voltage



For +ve half cycle,
D_2 work as regular diode and have voltage drop of 0.7v, while D_1 work as zener diode with voltage drop 6.2 v, so
$V_o = 0.7 + 6.2 = 6.9$ v

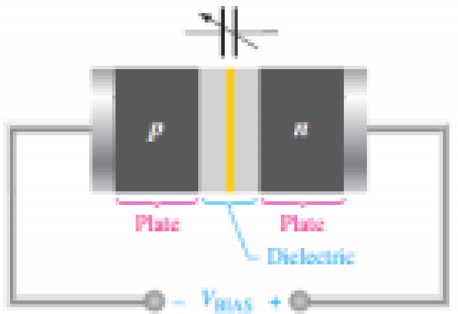
For -ve half cycle,
D_1 work as regular diode and have voltage drop of (- 0.7)v, while D_2 work as zener diode with voltage drop (-15.0)v, so
$V_o = -0.7 - 15.0 = -15.7$ v

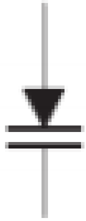


Other diodes types

1-Varactor

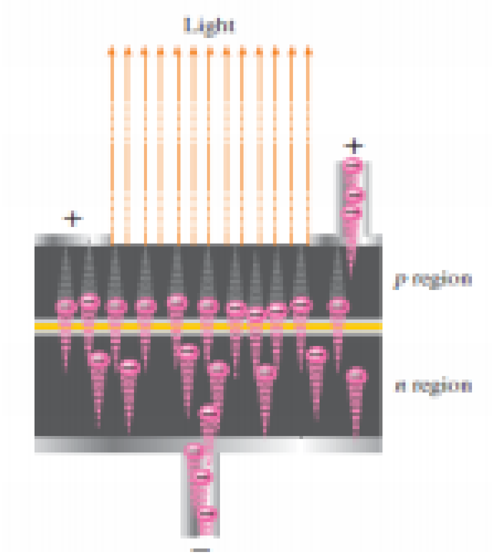
- **Varactor** is a diode that always operates in reverse bias
- It is doped to maximize the inherent capacitance of the depletion region.
- The depletion region acts as a capacitor dielectric because of its nonconductive characteristic.
- The *p* and *n* regions are conductive and act as the capacitor plates
- ***Act as variable capacitor***



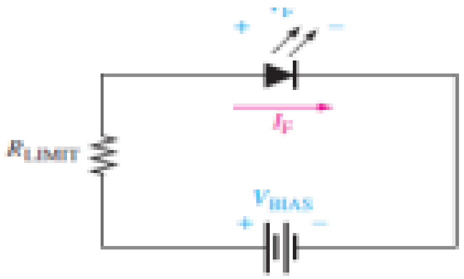


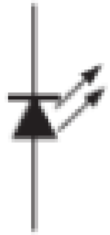
$$C = \frac{\varepsilon A}{d}$$

2- The Light-Emitting Diode (LED)



- For forward-biased, electrons cross the *pn* junction from the *n*-type material and recombine with holes in the *p*-type material.
- these free electrons are in the conduction band and at a higher energy than the holes in the valence band.
- The difference in energy between the electrons and the holes corresponds to the energy of visible light



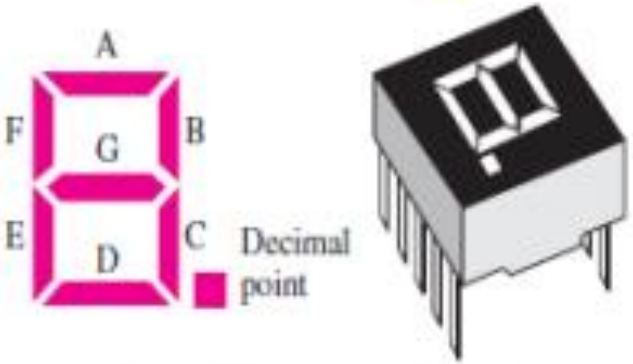


(a) Typical small LEDs for indicators

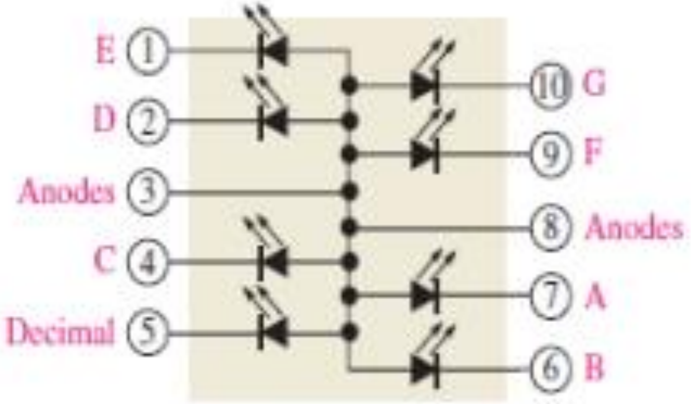
LED lamps are designed to work in 120 V standard fixtures.

Traffic lights

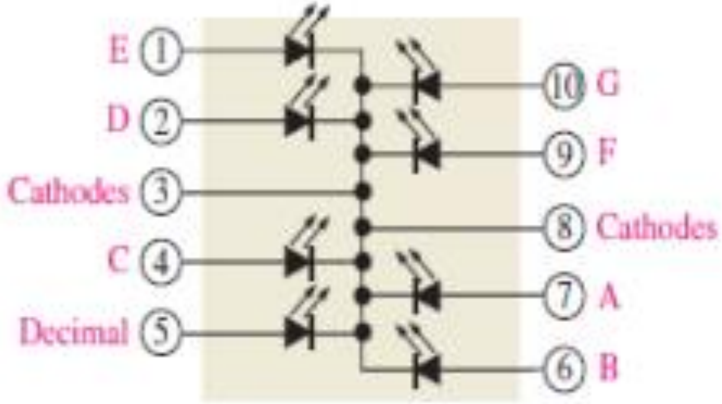
i. Seven segment display



(a) LED segment arrangement and typical device



(b) Common anode



(c) Common cathode


Thank
you